Early Ordovician Lingulate Brachiopods from New South Wales

IAN G. PERCIVAL[1] AND MICHAEL J. ENGELBRETSEN[2]

[1]Geological Survey of New South Wales, Department of Primary Industries, 947-953 Londonderry Road, Londonderry, NSW 2753, Australia (ian.percival@dpi.nsw.gov.au); and
[2]Centre for Ecostratigraphy and Palaeobiology, Department of Earth and Planetary Sciences, Macquarie University 2109. NSW. Australia.

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Lingulate brachiopods from the Lower Ordovician (lower *Oepikodus evae* conodont zone) Rowena Formation in the far west of New South Wales are revised, and determined as *Hyperobolus mootwingeensis* (Fletcher, 1964), *Lingulobolus gnaltaensis* (Fletcher, 1964), and the new genus *Rowenaglossa*, with type species *R. brunnschweileri* (Fletcher, 1964). Specimens possibly conspecific with *Lingulobolus gnaltaensis* are illustrated from Pine Gap, near Alice Springs, Northern Territory. In central western NSW, Early Ordovician (Lancefieldian-Bendigonian) brachiopods are represented in the Yarrimbah Formation of the Parkes region by the new species *Palaeoglossa yarrimbahensis*, a probable zhanatellid and an indeterminate acrotretide. Allochthonous limestones in the Hensleigh Siltstone, south of Wellington, of slightly younger (Bendigonian) age, yield *Otariconulus* sp. cf. *O. intermedia* and an unnamed new ephippelasmatid. Although broadly contemporaneous, the lingulide brachiopods documented in this paper lived in contrasting environmental settings. Those from the Koonenberry Belt in the far west inhabited nearshore predominantly sandy substrates, whereas faunas from central western NSW lived in deeper water outer shelf and slope to basinal environments flanking the Macquarie Arc.

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KEYWORDS: acrotretide, brachiopod, Koonenberry Belt, lingulide, Macquarie Arc, Ordovician

INTRODUCTION

Taxonomic work on Early Ordovician lingulate brachiopods from New South Wales has previously been restricted to description of three lingulide species from siliciclastic Lower Ordovician strata of the Gnalta Shelf in the far west of the state (Fletcher 1964). Advances in our understanding of Ordovician lingulides over the ensuing four decades, due chiefly to a proliferation of taxonomic research on the part of a small number of palaeontologists in Europe and Russia specializing in this group, allows revision of these species, which occur in the lower Rowena Formation within the Mutawintji National Park, northeast of Broken Hill (Fig. 1). Early Ordovician lingulates are rarely encountered elsewhere in the state, with the exception of the Yarrimbah Formation near Parkes that is dominated by *Palaeoglossa yarrimbahensis* sp. nov. Acrotretides are represented by just a handful of specimens from this unit and the slightly younger Hensleigh Siltstone, south of Wellington (Fig. 1). Here we describe and illustrate all known Early Ordovician lingulide and acrotretide brachiopods from New South Wales. As such brachiopods are becoming increasingly significant in global biogeographic analysis, their documentation is crucial even if based on limited material. This is especially true for Australia, where contemporaneous lingulate brachiopods remain very poorly known (Percival 2000), with the exception of a largely endemic fauna recently described from the Emanuel Formation of the Canning Basin, Western Australia (Brock and Holmer 2004). None of the latter species is represented in the faunas documented herein.

STRATIGRAPHIC SETTING

Central Koonenberry Belt (Mootwingee - Mount Wright area), far western NSW

The latest Cambrian to Early Ordovician Mutawintji Group [previously the Mootwingee

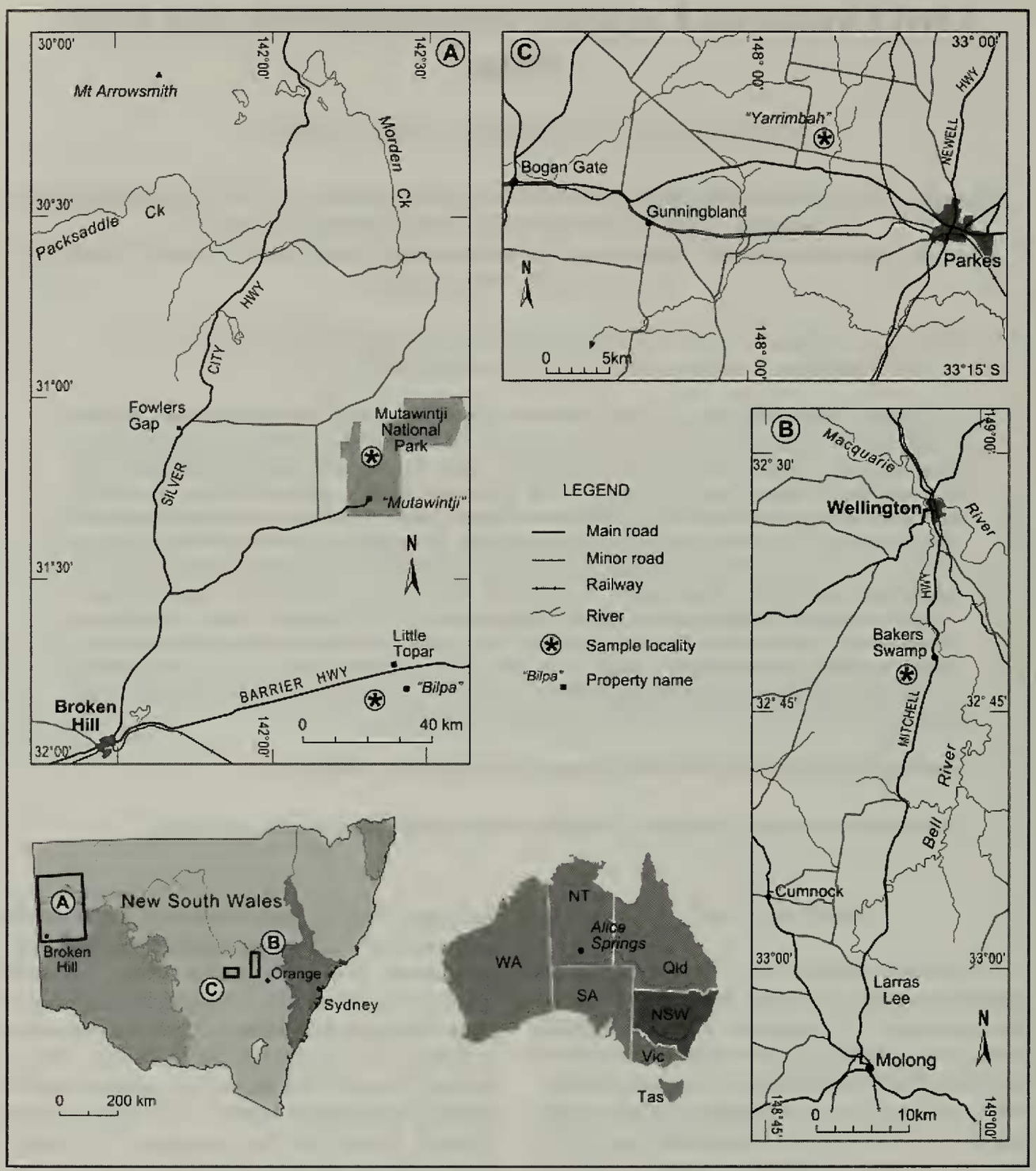

Figure 1. Locality map showing sites (indicated by stars) in New South Wales yielding Early Ordovician lingulate brachiopods described in this paper.

Group; the change in spelling was requested by the indigenous Mutawintji people to reflect its correct pronunciation in the Parrkantyi language; T. Sharp, pers. comm. 2003] includes (in ascending order) the Nootumbulla Sandstone, Bynguano Quartzite and Rowena Formation (Fig. 2). All three units consist predominantly of coarse siliciclastic sediments deposited in marginal marine to shallow shelf conditions. The Rowena Formation also comprises thin calcareous siltstone beds in the lower part of the unit. From one such horizon, Zhen and Percival (2006) reported a small but diverse conodont fauna dominated by *Erraticodon patu*, a species characteristic of the Early Ordovician *evae* Zone in the Tabita Formation at Mount Arrowsmith in the northern Koonenberry Belt (Zhen et al. 2003). Fletcher (1964) described

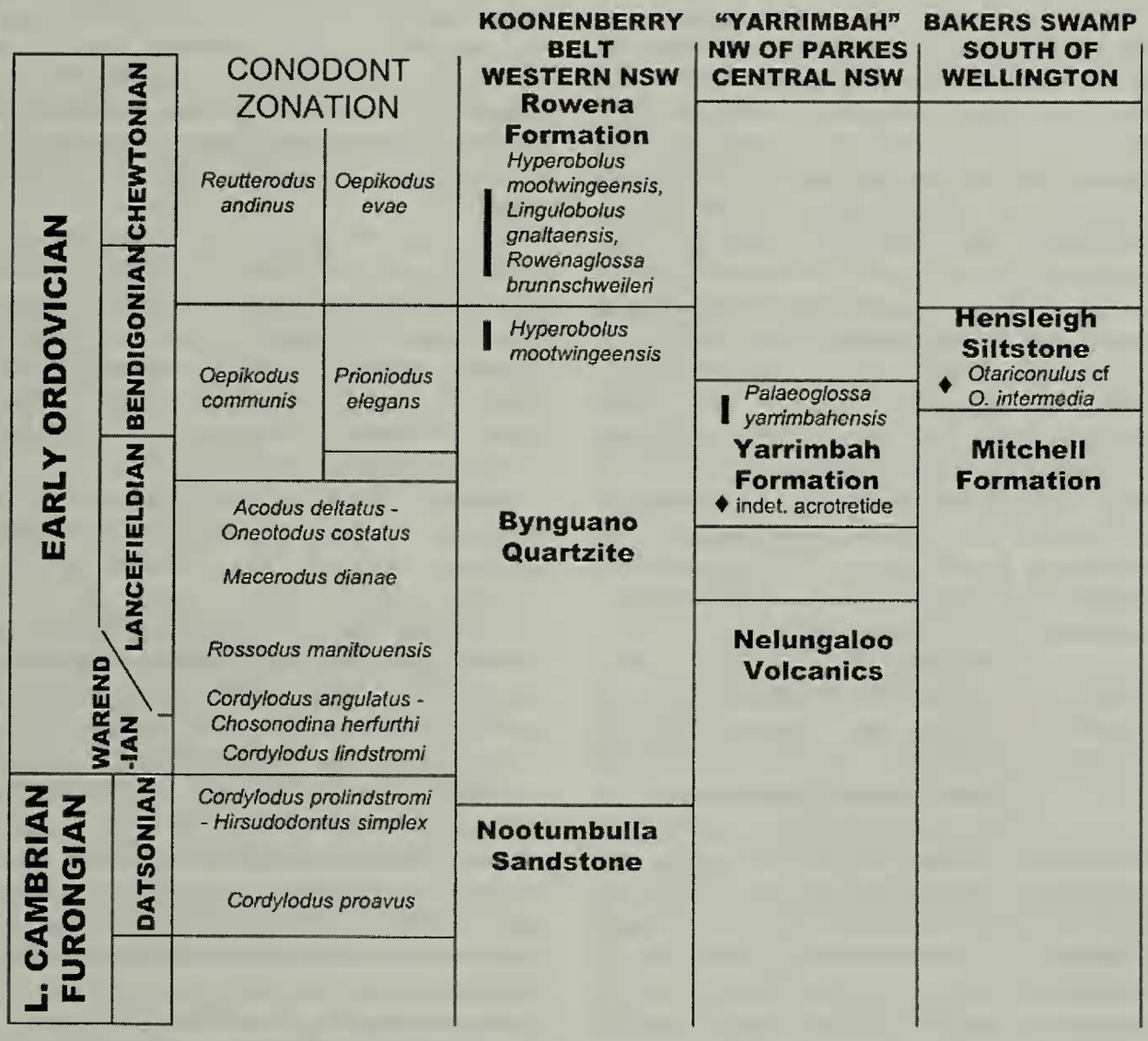

Figure 2. Stratigraphic levels at which Early Ordovician lingulate brachiopods occur in New South Wales.

Obolus mootwingeensis, *Lingulella* (*Leptembolon*) *gnaltaensis*, and *Ectenoglossa brunnschweileri* from outcrops of the Rowena Formation (then known as the upper part of the Gnalta stage of the Mootwingee Series) in the vicinity of the disused Mootwingee-White Cliffs mail coach road. The exact localities from which the specimens described by Fletcher were obtained are not known (they are noted in the Australian Museum register as "8 miles along the coach road from Mootwingee"). The most recent geological map of Mutawintji National Park (Sharp 2004) shows that the Rowena Formation intersects the old coach road along strike over a distance of approximately 10 km. Most likely the type localities are centred on GR 654505 mE 6270000 mN (Nuchea 7335 1:100,000 mapsheet, GDA94 coordinates) as there are abundantly fossiliferous outcrops in the immediate vicinity. Since Fletcher's pioneering work no further research has been conducted into these brachiopods. Revision of the type and topotype material reveals new information about the internal features of these brachiopods and allows reassessment of their taxonomic status. All three taxa are reassigned at genus level to *Hyperobolus mootwingeensis*, *Lingulobolus gnaltaensis*, and the new genus *Rowenaglossa*, with type species *R. brunnschweileri*. Specimens of *H. mootwingeensis* and *L. gnaltaensis* (collected in the mid-1960s, and curated in the Geological Survey of NSW palaeontological collection) also occur sporadically in the Bynguano Quartzite at a locality three miles (approximately five km) west of "Bilpa" homestead, ten miles (16 km) south of Little Topar, in the southern extremity of the Koonenberry Belt (Fig. 1).

Macquarie Arc, Lachlan Orogen, central NSW

The Yarrimbah Formation, exposed on "Yarrimbah" property, 16 km west of Parkes (Fig. 1), has most recently been defined by Sherwin (2000). Graptolites identified by Sherwin (1979, 1990; pers. comm. 1999) from laminated siliceous mudstones forming the upper beds of this unit include *Didymograptus* (*Cymatograptus*) sp., *Tetragraptus approximatus* and *Pendograptus fruticosus*. These indicate an age, in terms of the Victorian graptolite zonation, of late Lancefieldian to early Bendigonian (equivalent to the *approximatus* to *fruticosus* zones of the Australasian and Chinese successions). Lingulide brachiopods including prolific *Palaeoglossa yarrimbahensis* sp. nov., and a possible zhanatellide (the latter exceptionally rare) are the only other fossils found in the upper Yarrimbah Formation. One specimen of an indeterminate acrotretide with a distinctive dorsal platform was recovered from allochthonous limestone clasts that occur sporadically in the lower part of the formation.

From the Hensleigh Siltstone in the Bakers Swamp area, 26 km south of Wellington (Fig. 1B), acrotretide brachiopods are represented by only a couple of specimens. Two taxa, *Otariconulus* sp. cf. *O. intermedia* and ephippelasmatidae gen. et sp. nov. (insufficient material is available to permit formal naming), are described herein from allochthonous limestones in the lower part of this formation. The age of the Hensleigh Siltstone, based on graptolites, is middle to late Bendigonian (Be 2-3) (Percival et al. 2001). Conodonts obtained from the allochthonous limestones indicate an age equivalent to the upper *Prioniodus elegans* conodont Biozone, contemporaneous with the *Oepikodus communis* conodont Biozone (Zhen et al. 2004).

COMPARATIVE PALAEOECOLOGY

Lower Ordovician rocks of the Mutwintji Group were deposited in a nearshore shallow marine setting on the Delamerian margin of Gondwana, as indicated by trace fossils attributed to trilobites (Webby 1983) and a diverse infauna (Droser et al. 1994) in the Bynguano Formation (immediately underlying the Rowena Formation). The lingulide brachiopods redescribed herein from the lower Rowena Formation present a further opportunity for palaeoecological analysis, based on comparisons with studies of similar faunas in contemporaneous clastic rocks of central Europe.

In the Prague Basin (Czech Republic), the *Hyperobolus* Community is interpreted as having inhabited the most shallow water nearshore setting (Havlíček 1982a), where *Hyperobolus feistmantelli* (associated with other large and moderate to thick-walled lingulates) lived in a semi-endobenthic habit, i.e. being only partly or shallowly buried in an unconsolidated sandy sea floor (Mergl 2002). Not surprisingly, considering its close morphological similarity, the Gnalta Shelf species *H. mootwingeensis* seems to have occupied an identical ecological niche.

Likewise, the presence of *Lingulobolus* and *Rowenaglossa* in the Rowena Formation recalls the co-occurrence of *Lingulobolus*? and the externally homeomorphic *Ectenoglossa* in the Armorican Sandstone of Brittany and the Montagne Noire regions of France, in similar low diversity faunas entirely dominated by large lingulate brachiopods (Cocks and Lockley 1981).

However, there are subtle differences in the distribution of these lingulates in the Rowena Formation, compared with European nearshore lingulate-dominated faunas. Firstly, the faunal diversity of the Rowena Formation is somewhat lower (three lingulate genera) than formations in the Prague Basin (five to six genera in the Třenice Formation). Secondly, the Rowena Formation lingulates are not associated in the one horizon; rather, they occur as monospecific shell beds, with *Hyperobolus* and *Lingulobolus* confined to separate sandy quartzose sediments, whereas *Rowenaglossa* generally occurs in slightly finer lithofacies (silts rather than coarse sands). Such variance in facies preference may present an opportunity to more precisely define depth-related communities in order to study transgressive-regressive relationships in the Mutawinjti Group.

In contrast, *Palaeoglossa* in the Yarrimbah Formation inhabited deep-water substrates. Although no graptolites are found in direct association with the brachiopod-bearing laminated siltstones, unlike comparable occurrences in the Upper Ordovician Malongulli and Gunningbland Formations (Percival 1978), graptolites are plentiful in directly underlying beds, implying that water depth throughout deposition of the Yarrimbah Formation was considerable. Sponges, indicated by abundant spicules preserved in the Malongulli Formation, may have provided a substrate above the sediment-water interface for some or all of the lingulate brachiopods found in that unit; the apparent absence of sponge remains in the Yarrimbah Formation suggests that *P. yarrimbahensis* lay sessile on the sea floor or else may have lived partly buried. Acrotretide brachiopods found in allochthonous limestone clasts in both the Yarrimbah and Hensleigh formations are interpreted as living on outer carbonate shelves flanking volcanic islands at relatively shallow depths, prior to displacement downslope.

SYSTEMATIC PALAEONTOLOGY

Type material, comprising specimens described and illustrated or listed herein, is curated in the palaeontological collections of the Geological Survey of New South Wales (designated MMMC for microfossil specimens, and MMF for macrofossils), or in the type fossil collection of the Australian Museum, Sydney (AM F). Responsibility for taxonomic description and authorship of new taxa is attributable to I.G. Percival for Lingulida, and M.J. Engelbretsen for Acrotretida. For brevity, authorship of taxonomic hierarchy above genus level is not cited in the References; these bibliographic sources are listed in the revised (2nd edition) Treatise of Invertebrate Paleontology, Part H: Brachiopoda (Williams et al. 2000).

Phylum Brachiopoda Duméril, 1806
Subphylum Linguliformea Williams, Carlson, Brunton, Holmer & Popov, 1997
Class Lingulata Gorjansky & Popov, 1985
Order Lingulida Waagen, 1885
Superfamily Linguloidea Mencke, 1828
Family Obolidae King, 1846
Subfamily Obolinae King, 1846

***Palaeoglossa* Cockerell, 1911**
Type species: *Lingula attenuata* J. de C. Sowerby, 1839

***Palaeoglossa yarrimbahensis* sp. nov.**
Fig. 3A – M, 4D – N

Material

Holotype MMF 27463c; paratypes MMF 27621a, MMF 30329a, MMF 44823 – 44832 inclusive.

Diagnosis

A species of *Palaeoglossa* with a very short ventral pseudointerarea; internally with scattered pustules and fine pitting posteriorly; very fine radial striations crowded around interior periphery of valves; umbonal muscle scars confined to immediate vicinity of pedicle groove; dorsal valve lacking median ridge internally.

Description

Ventral valve elongately ovoid in outline with broadly acute posterior end; dorsal valve tending toward subcircular outline with rounded posterior; lateral margins of both valves very gently curved to subparallel; maximum width in both valves approximately coincident with midlength; shell profile lenticular, weakly biconvex. Length:width ratio ranges from 1.28-1.61 for ventral valves (average 1.33) and ranges from 1.08-1.22 (average 1.15) for dorsal valves. Shell material moderately thin; ornament confined to closely spaced hemiperipheral growth lines (Fig. 4D), occasionally with accentuated growth discontinuities (Fig. 3L), but lacking any radial striations externally.

Ventral pseudointerarea reduced to pair of small short triangular propareas flanking open pedicle groove (Fig. 4G); flexure lines absent. Muscles generally not deeply inserted, although paired umbonal muscle scars are occasionally prominent in the immediate vicinity of the pedicle groove (Figs. 3C, D, K, J), and paired anterior adductor scars with relatively well-defined inner margins appear to be present medially in one specimen (Fig. 3M). Isolated small irregular pustules scattered on interior of valve (Fig. 3C). Pallial canals not impressed.

Dorsal pseudointerarea extremely short but apparently complete and undivided (Fig. 3I). Although muscle scars are rarely impressed, an umbonal scar (possibly paired: Fig. 4N) and some ill-defined visceral markings may be visible posteriorly (e.g. Figs 3H, I). Scattered pustules occasionally present (Fig. 3L). One well-preserved internal mould (Fig. 4M) shows evidence of very fine scattered pits in visceral area. Pallial canals unknown. Margin of dorsal valve displays very fine radial striations in better-preserved specimens (Fig. 3I).

Dimensions

Holotype MMF 27463c length 11.0 mm, width 8.2 mm. Smallest specimen is a subcircular juvenile dorsal? valve (MMF 44832) 3.4 mm in length and 3.1 mm in width; subsequent hemiperipheral growth accentuates elongation in adults, especially in ventral valves, whereas dorsal valves may retain a subcircular outline even in large adult specimens (e.g. Figs 4E, F). Ventral valve length ranges from 5.1-11.1 mm, dorsal valve length ranges from 7.9-12.7 mm; ventral valve width ranges from 4.1-8.7 mm and dorsal valve width ranges from 6.5-11.7 mm.

Discussion

The type species of *Palaeoglossa*, *P. attenuata* (J. de C. Sowerby, 1839), from the Middle Ordovician of the Shelve area, Shropshire, England (most recently redescribed by Sutton et al. 1999), lacks flexure lines in both pseudointerareas, and has internal features such as muscle scars and pallial canals very weakly impressed, with only sporadic pitting weakly

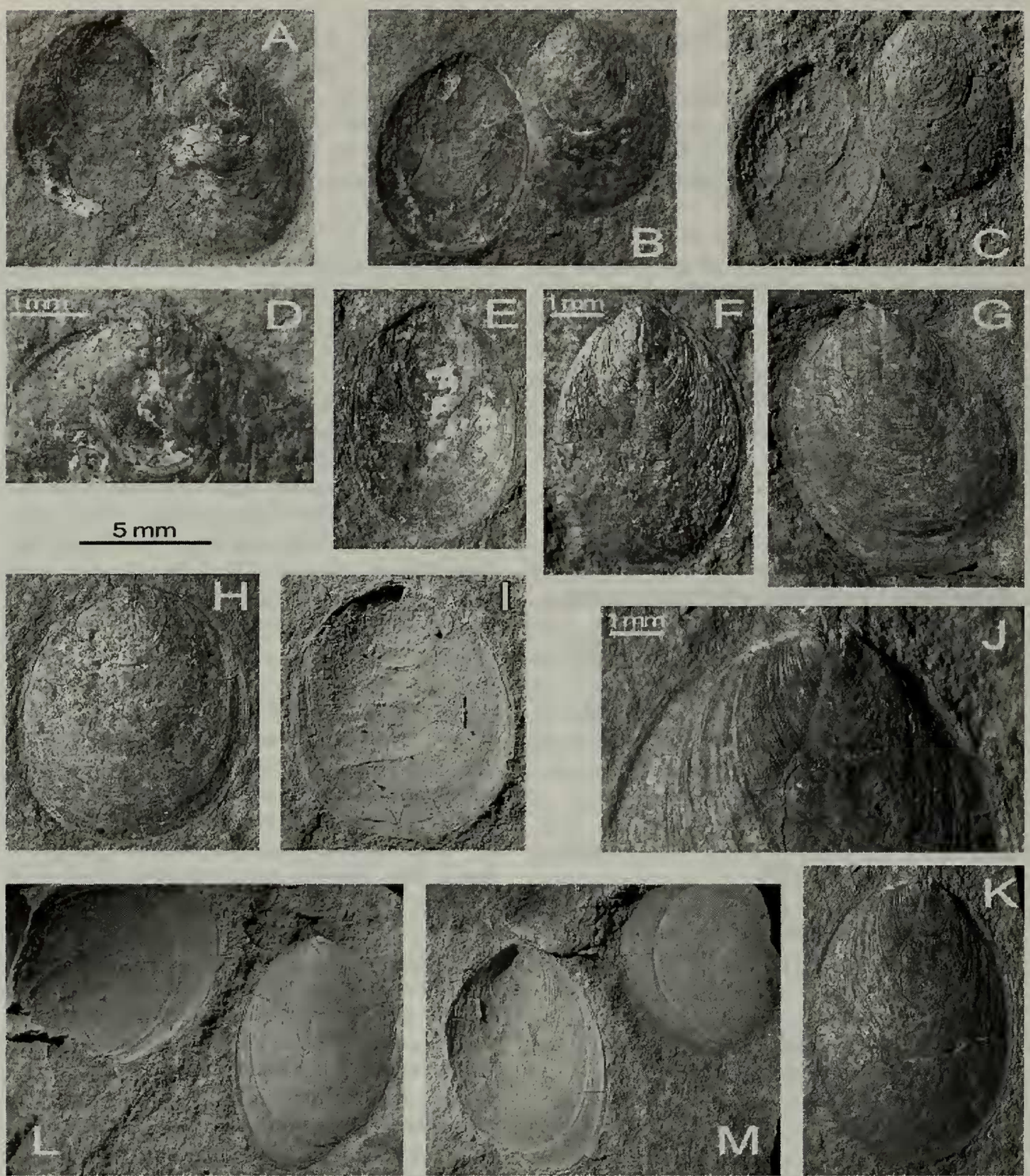

Figure 3. ***Palaeoglossa yarrimbahensis*** **sp. nov. from the upper Yarrimbah Formation, west of Parkes, central west NSW. A – D: Two valves presumed to represent the one individual, MMF 44830; A, B, part and counterpart and C, latex replica taken from A; A: internal mould of dorsal valve (on left) and ventral valve (on right); B: partly exfoliated ventral valve (on left) and exterior of dorsal valve (on right); C: latex replica clearly shows nearly circular juvenile shell on dorsal valve (right) and scattered pustules on interior of ventral valve (left); note also deeply inserted umbonal muscle scars in this valve; D: Enlargement of posterior of ventral valve internal mould. E: ventral valve internal mould, MMF 44831. F. ventral valve internal mould, MMF 44823. G. ventral valve internal mould, MMF 30329a, slightly distorted. H – I: dorsal valve internal mould and latex replica, MMF 44827. J – K: Holotype, ventral valve internal mould, MMF 27463c, J is an enlargement of posterior to show pedicle groove. L – M: dorsal and ventral valves, possibly of the one individual, both are latex replicas taken from MMF 44824; both valves incomplete, with ventral valve vertically oriented in both photographs. Scale bar above H applies to all specimens except D, F and J.**

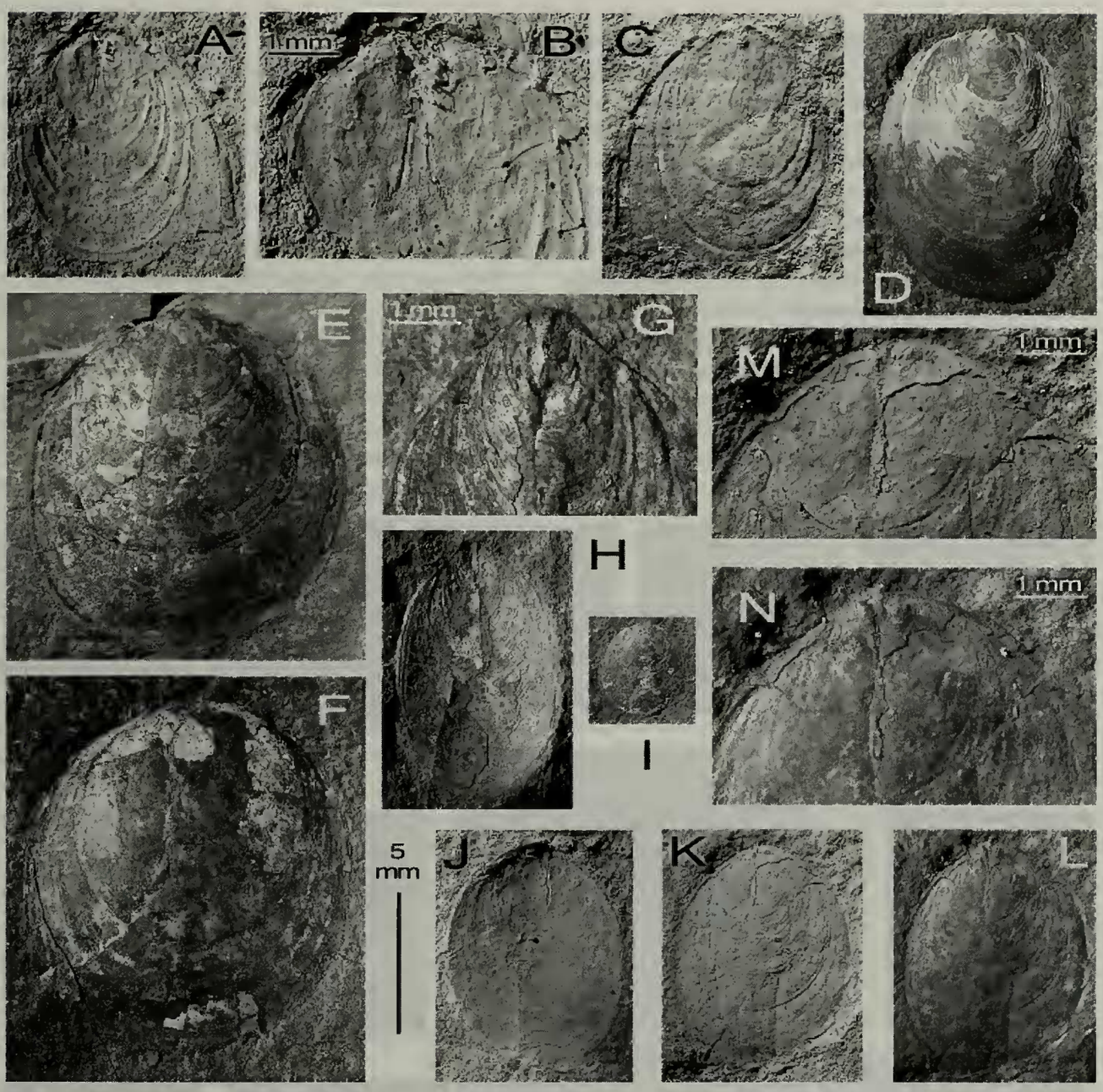

Figure 4. Lingulate brachiopods from the upper Yarrimbah Formation, west of Parkes, central west NSW. A – C: zhanatellide indet., internal mould (C) and latex replicas (B is enlargement of posterior region) of ventral valve MMF 44843. D – N: *Palaeoglossa yarrimbahensis* sp. nov. D: ventral? valve exterior view, displaying ornament of growth lines only, MMF 44828; E: dorsal valve internal mould, MMF 44829. F: dorsal valve internal mould with adherent shell, MMF 27621a. G –H. ventral valve internal mould (H) and enlargement of posterior region (latex replica) to show pedicle groove, MMF 44825. I: juvenile dorsal? valve, partly exfoliated internal mould, MMF 44832. J – N: dorsal valve internal mould (L), and two latex replicas, (J) taken from that specimen and (K) from counterpart external mould, (M) and (N) are enlargements of posterior regions of (K) and (L) respectively, MMF 44826. Scale bar between F and J applies to all specimens except B, G, M and N.

developed internally in both valves. In all these characteristics it resembles the Yarrimbah species. The main features distinguishing *P. attenuata* and *P. yarrimbahensis* concern the complete absence in the latter of any median ridge in the dorsal valve (a weak median septum is occasionally developed in *P. attenuata*), and the greatly reduced length of the ventral pseudointerarea in *P. yarrimbahensis*, resulting in a much less acuminate outline of the ventral valve beak.

Lingulella, which appears to be closely related to *Palaeoglossa* according to Sutton et al. (1999), was also considered as a possible generic assignment.

Sutton et al. (2000) redescribed the type species of *Lingulella*, *L. davisii* McCoy, 1851 from the Upper Cambrian of North Wales, noting its diagnostic characters as ventral propareas with well-defined flexure lines, conspicuous deep pitting on interiors of both valves, anterior lateral and central muscle scars set close together, and *vascula lateralia* subperipheral to peripheral, not sharply divergent proximally. Fine sporadic pitting on the interior of *P. yarrimbahensis* is neither as strongly developed nor as dense as that which characterizes *L. davisii*. Furthermore, features exhibited by the Yarrimbah species including very reduced pseudointerareas lacking flexure lines, and absence of any anterior extension of the dorsal visceral field as a ridge or tongue, are atypical of *Lingulella*.

Distribution

Outcrop of upper Yarrimbah Formation adjacent to "Yarrimbah" and "Wilga East" property boundary, 16 km west of Parkes (Fig. 1C); late Lancefieldian (La3) to early Bendigonian (Be1).

***Lingulobolus* Matthew, 1895**

Type species: *Lingulella*? *affinis* Billings, 1872

***Lingulobolus gnaltaensis* (Fletcher, 1964)**

Fig. 5 A – M

Synonymy

1964 *Lingulella* (*Leptembolon*) *gnaltaensis* Fletcher, p. 287, pl. 31, figs 7, 9.

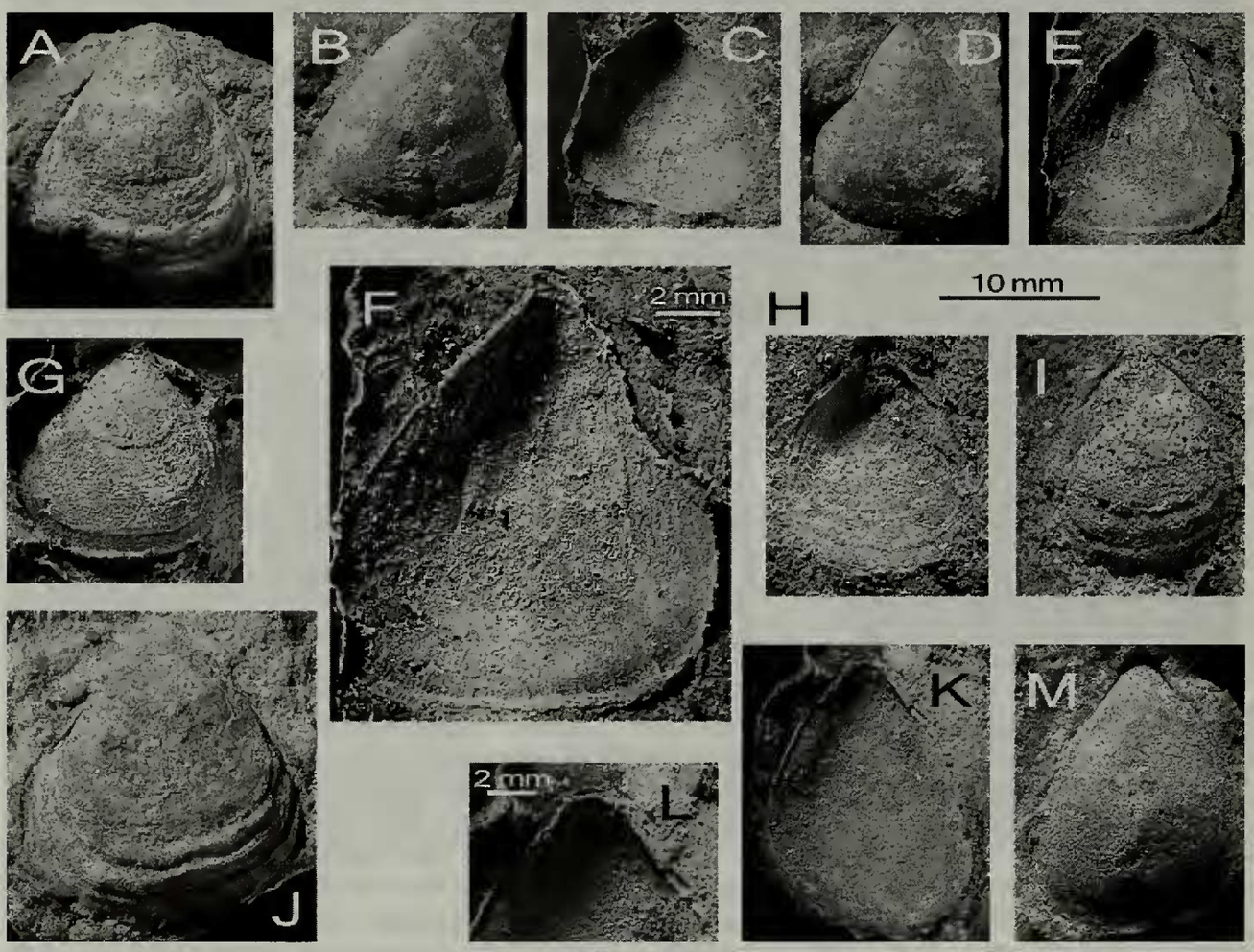

Figure 5. ***Lingulobolus gnaltaensis*** **(Fletcher, 1964), from the lower Rowena Formation, Koonenberry Belt, far western NSW. A: exterior of ventral? valve, holotype AM F49383; B – C: dorsal valve, internal mould and latex replica, AM F50411; D – F: ventral valve, internal mould and latex replica, enlarged in F to more clearly show muscle field, AM F50415; G: exterior of dorsal valve (latex replica from external mould), AM F50401; H – I: interior (latex replica) and internal mould of dorsal valve, AM F47492; J: exterior of ventral? valve (latex replica from external mould), AM F49384; K – M: latex replica of dorsal internal mould shown in M, with enlargement of posterior half of valve shown in L, AM F132242. Scale bar beneath D and E applies to all specimens except F and L.**

Material

Holotype AM F49383 and paratype AM F49384 (not 49344, a typographical error in Fletcher 1964, p. 287), both internal moulds of ventral valves (designated by Fletcher 1964); additional paratypes selected herein are AM F47492, AM F50401, AM F50411, AM F50415 and AM F132242 (illustrated in Fig. 5).

Description

Shell broadly triangular in outline with subacuminate beak in ventral valve, and with maximum width attained about three-quarters length from beak; length almost always greater than width in ventral valves, but equal to or somewhat less than width in dorsal valves; moderately to strongly biconvex especially anteriorly; occasionally with fine growth lamellae and stronger concentric rugae developed anteriorly, most prominent in larger specimens (Fig. 5 A, C); no radial ornament. Ventral pseudointerarea possibly undivided, very much reduced in length (Fig. 5 L, M). Ventral valve muscle field [well-displayed on specimen AM F50415 (Fig. 5 F)] is confined to posterior half of valve where it consists of a median parallel track of anterior adductor scars(?) flanked by pair of shorter but wider impressions (oblique muscle scars?) that slightly diverge, and are bounded laterally by traces of narrow linear pallial canals; fine closely-spaced radial striae are impressed around anterior margin of this specimen. Dorsal valve interior (Fig. 5 H) is essentially smooth and lacks impressed muscle scars and vascular markings; pseudointerarea possibly entire but very short and poorly preserved.

Dimensions

Holotype AM F49383: length 16.5 mm, width 14.1 mm. For other complete specimens, ventral valve length ranges from 13.3-17.3 mm, dorsal valve length ranges from 7.9-12.7 mm; ventral valve width ranges from 11.8-17.6 mm and dorsal valve width ranges from 11.3-12.5 mm.

Discussion

Although Fletcher (1964) stated in his description of *Lingulella* (*Leptembolon*) *gnaltaensis* that only brachial (i.e. dorsal) valves were figured, this was corrected to pedicle valves in the caption to his plate 31. *Leptembolon* Mickwitz, 1896, is close to *Lingulobolus* as regards shell outline and profile, but internally the two genera are readily distinguished by the greatly thickened ventral visceral area of the former and its slightly thickened dorsal visceral area that extends as a low ridge nearly to the anterior valve margin. As none of these features are apparent in Fletcher's species its reassignment to *Lingulobolus* is therefore justified.

The diagnosis given for *Lingulobolus* by Holmer and Popov (2000) mentions a narrow subtriangular ventral pseudointerarea divided by a broadly triangular pedicle groove, with a vestigial undivided dorsal pseudointerarea, and a weakly defined dorsal visceral area extending beyond midlength with closely spaced anterior-lateral and central muscle scars. The genus is represented by *L. affinis* (Billings, 1872) and *L. spissus* (Billings. 1872), both from Lower Ordovician strata in Newfoundland, and possibly another two species of Early Ordovician age, *L.? hawkei* (Rouault, 1850), found in southern Britain and France (Brittany) (Cocks and Lockley 1981), and *L.? brimonti* (Rouault, 1850), co-occurring with *L.? hawkei* in these regions as well as in the Montagne Noire of France (Havlíček 1980) and in Algeria, North Africa (Legrand 1971). *Lingulobolus gnaltaensis* shows clear affinities with the Newfoundland species *L. spissus*, most recently illustrated by Holmer and Popov (2000, p. 47), in shell outline, profile, rhomboidal shape of the ventral visceral area, and disposition of fine radial striae in a peripheral band at the anterior margin of the ventral valve. However, in having a much reduced ventral pseudointerarea without a distinct pedicle groove (although this may be due to adverse preservation in coarse clastic sediment) it differs from the Canadian species. The external coarse rugae developed on *L. gnaltaensis*, and lack of any exterior radial ornament, are another distinguishing feature (compare with detailed line drawings of both Newfoundland species given by Walcott 1912, pl. XVI). Generally poor preservation of *L.? hawkei* and *L.? brimonti* does not permit meaningful comparisons with *L. gnaltaensis*.

Distribution

Lower Rowena Formation, "about 8 miles (13 km) from 'Mootwingee' homestead along old coach road" according to Australian Museum register, just east of Split Rock in Mutawintji National Park, far-western NSW (Fig. 1A). Also occurs sporadically in the Bynguano Quartzite in the southern Koonenberry Belt, 16 km south of Little Topar (Fig. 1A) (MMF 15013, 15014, 15017, 15019, 15021).

***Lingulobolus* cf. *L. gnaltaensis* (Fletcher, 1964)**

Fig. 6 A – E

Discussion

Fletcher (1964) noted that his *Lingulella* (*Leptembolon*) *gnaltaensis* was possibly congeneric with specimens from the Pacoota Sandstone at a

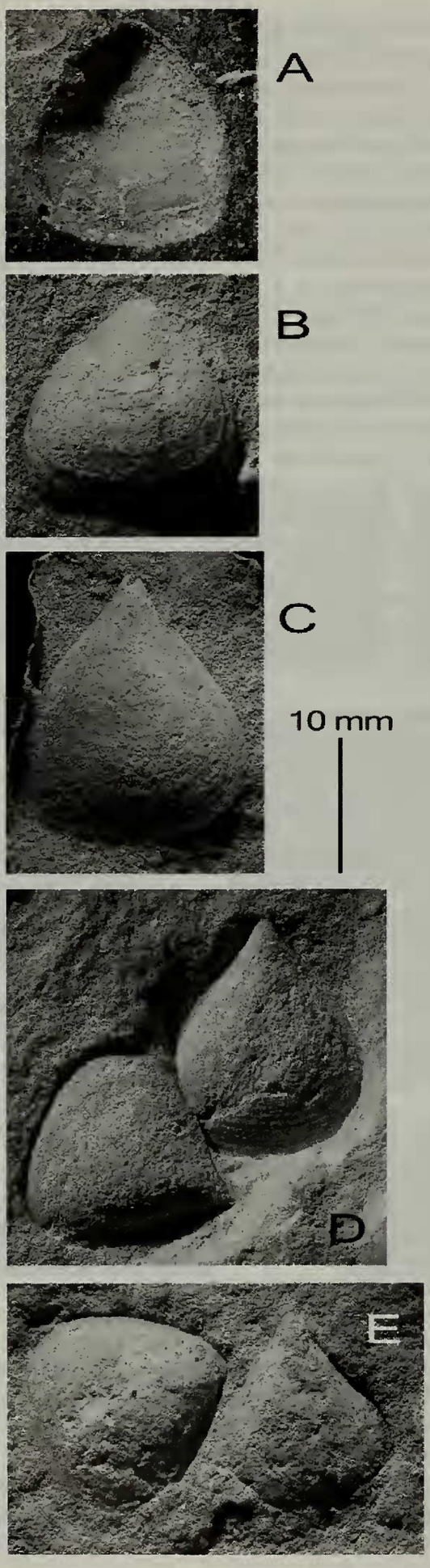

Figure 6. ***Lingulobolus*** **cf.** ***L. gnaltaensis*** **(Fletcher, 1964), from the Pacoota Sandstone, Pine Gap near Alice Springs, Northern Territory. All specimens are located on one slab bearing the Australian Museum number AM F49586. A: latex replica of interior of dorsal valve, AM F49586g; B: latex replica of exterior of dorsal valve, AM F49586f; C: latex replica of exterior of ventral valve, AM F49586e; D: two ventral valve internal moulds, one partly exfoliated, AM F49586a, b; E: dorsal (left) and ventral (right) valve internal moulds, possibly from the one individual, AM F49586c, d.**

locality (Pine Gap), about 19 km southwest of Alice Springs, Northern Territory. He neither described nor illustrated these specimens, and to our knowledge they have not subsequently been documented. Material from the Pine Gap locality (now a restricted military site) that was available to Fletcher was located in the Australian Museum collection, and representative specimens are here illustrated in Figure 6. Little can be said about these shells other than their gross morphology, as the coarse sandstone matrix has prevented preservation of subtle internal features. They seem to be slightly larger than *Lingulobolus gnaltaensis*, but otherwise could well be conspecific. Shell outline and profile appears near identical for both the Rowena Formation and Pine Gap forms. In the absence of internal features we tentatively compare the latter with *L. gnaltaensis*.

Dimensions

AM F49586a (ventral valve) length 20 mm, width 17.5 mm; AM F49586b (dorsal valve) length 16.4 mm, width 16.6 mm; AM F49586c (ventral valve) length 18.8 mm, width 15.3 mm; AM F49586d (ventral valve) length 16.7 mm, width 16.2 mm; AM F49586e (dorsal valve) length 15.5 mm, width 15.3 mm.

Family Pseudolingulidae Holmer, 1991

Rowenaglossa **gen. nov.**

Type species: *Ectenoglossa brunnschweileri* Fletcher, 1964

Diagnosis

Outline spatulate to elongate rectangular with subparallel lateral margins; ventral pseudointerarea extending about one-third valve length, divided by narrow but deep pedicle groove; median septum prominent in dorsal valve, much reduced or absent in

ventral valve; muscle scars and pallial canals weakly impressed.

***Rowenaglossa brunnschweileri* (Fletcher, 1964)**
Fig. 7 A – P

Synonymy

1964 *Ectenoglossa brunnschweileri* Fletcher, p. 288, pl. 31, figs 4-6; pl. 32, fig 15.

Material

Holotype AM F49027 ventral valve, and paratypes AM F48995 (ventral valve) and AM F49014 (dorsal valve), designated by Fletcher (1964); an additional specimen AM F49044 was illustrated by Fletcher but not included in the original type series. It, together with specimens AM F48975, AM F49001, AM F49011, AM F49034, AM F49050 and AM F49843 are here designated as additional paratypes (illustrated in Fig. 7).

Description

Shell outline spatulate, elongately acutely triangular to subrectangular; ventral beak narrowly acute, dorsal beak slightly less so; maximum width reached between approximately two-fifths and half valve length, after which lateral margins remain subparallel or very slightly converge towards anterolateral extremities; length to width ratio 1.6-2.28 (ventral valves), 1.6-2.34 (dorsal valves); shell profile weakly biconvex with maximum curvature restricted to lateral periphery of valves. Ornament of growth lines only (Fig. 7 E). Shell material moderately thick.

Ventral pseudointerarea narrowly triangular, extending to nearly one-third valve length (Fig. 7 A, B), separated by narrow pedicle groove (Fig. 7 J, L) that extends for several mm anteriorly, flexure lines apparently lacking; in one specimen a short slightly raised median ridge (Fig. 7 F, G) extends from front of weakly impressed umbonal scar; median ridge absent to very weakly developed medially; the anterior part of this ridge may be flanked by pair of low furrows that further accentuate it (Fig. 7 A, B); very weakly impressed central muscle scars may be present medially on either side of median ridge (Fig. 7 A) but other muscle scars and pallial canals not observed.

Dorsal pseudointerarea short, very narrow, entire but with very slight median depression to accommodate pedicle (Fig. 7 A, C, D, H); paired large median muscle scars (centrals) with subrectangular outline are weakly impressed between about midlength and two-thirds valve length (Fig. 7 H, I), bisected by a thin but prominent median septum that commences in posterior third of some dorsal valves and extends almost to anterior margin (Fig. 7 C, D, H, I, M, N); other muscle scars not impressed; *vascula lateralia* rarely visible (Fig. 7 I), slightly divergent and mostly straight.

Dimensions

Holotype AM F49027 (ventral valve): length 27.2 mm, width 12.3 mm. For other complete specimens, ventral valve length ranges from 15.2-24.5 mm, dorsal valve length ranges from 14.5-28.1 mm; ventral valve width ranges from 8.0-15.3 mm and dorsal valve width ranges from 9.0-13.3 mm.

Discussion

Fletcher (1964) referred this species to *Ectenoglossa* Sinclair, 1945, which has a distinctive spatulate to subrectangular outline near identical to that of the new genus. *Ectenoglossa* is, according to Holmer and Popov (2000), poorly known, particularly as regards details of the dorsal interior and the disposition of vascular markings in both valves. Within the concept of the genus these authors include only the type species *E. lesueuri* (Rouault, 1850), which occurs in Lower Ordovician rocks in Brittany and the Montagne Noire in France (Havlíček 1980), and in pebbles eroded from these units and redeposited in Devon, Britain (Cocks and Lockley 1981). Other species attributed to *Ectenoglossa* by Goryansky (1969), including *E. lata* and *E. exunguis*, more closely resemble *Pseudolingula* in outline and profile; *E. lata* in particular displays a prominent dorsal median septum, and Holmer (1991) suggested that it represented an undescribed new genus with close affinity to *Pseudolingula*. Cooper (1956) tentatively referred two species, *E*? *rubra* and *E*? *sculpta*, to *Ectenoglossa* based on external details only; their affinities remain unknown. A further species, *E. nymphoidea* Cooper, 1956, from Middle Ordovician strata of Tennessee and Virginia, is one of the largest known lingulate brachiopods, with lengths estimated up to 75 mm. Although other internal details are unclear, the presence of a dorsal median ridge in *E. nymphoidea* (Cooper 1956, pl. 2E, fig. 16) suggests this species may be better placed in *Pseudolingula*. A poorly preserved unnamed species provisionally attributed to *Ectenoglossa* from Meiklejohn Peak, Nevada (Krause and Rowell 1975) similarly displays a median ridge in a presumed dorsal valve, and is also more likely to be a pseudolingulide. Two additional species assigned to *Ectenoglossa* have been described from Upper Ordovician strata; *E. sorbulakensis* Popov, 1980, from the Chu-Ili Range region of Kazakhstan (see also Popov et al. 2002), and *E. minor* Zhan and

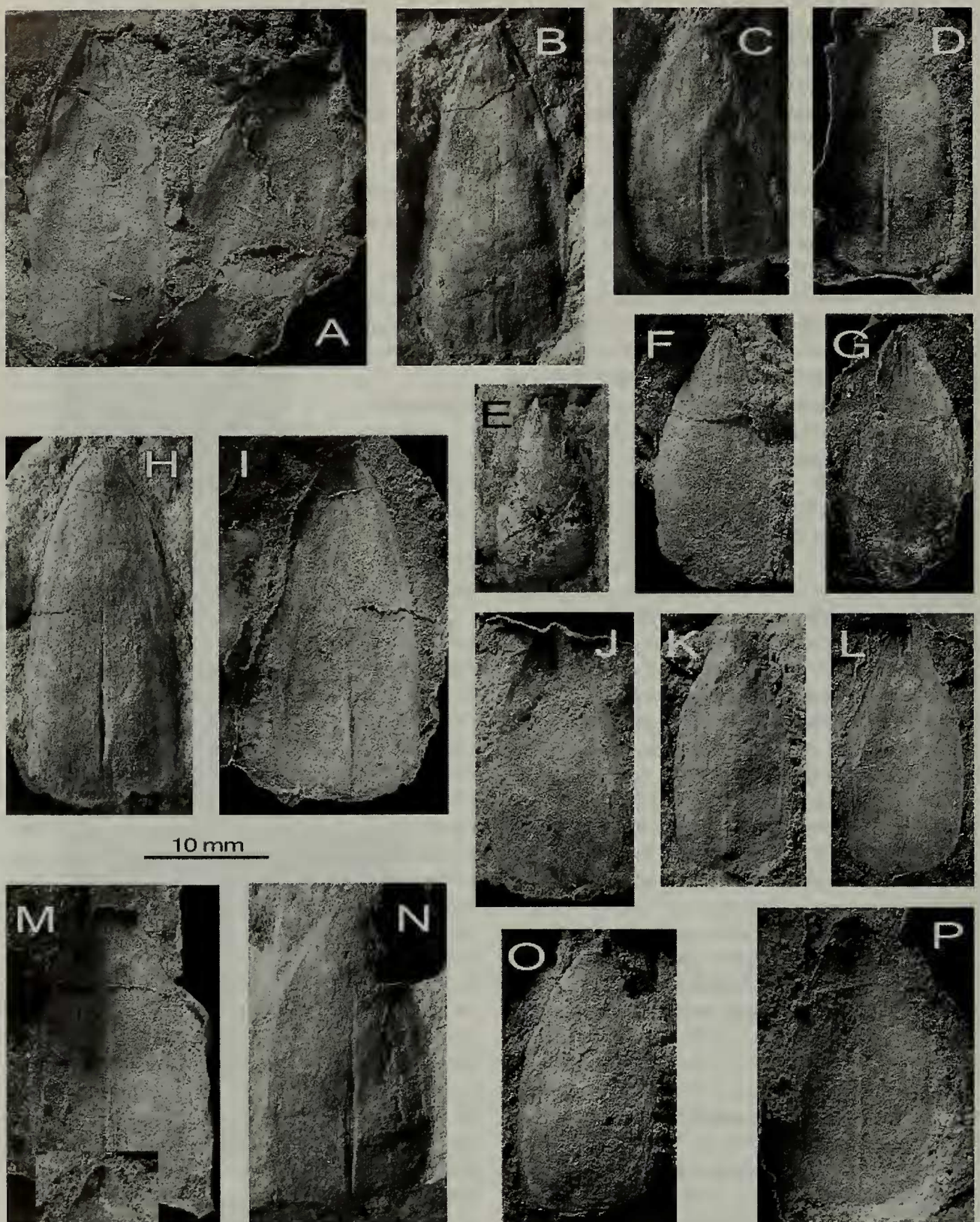

Figure 7. ***Rowenaglossa brunnschweileri*** **(Fletcher, 1964), from the lower Rowena Formation, Koonenberry Belt, far western NSW. A – B: ventral valve, holotype AM F49027, A is latex replica and B is internal mould (note that adjacent dorsal valve on right-hand side of A is presumed to be the opposing valve of this specimen); C – D: dorsal valve AM F49050, internal mould and latex replica; E: exterior of partly exfoliated juvenile ventral? valve AM F48975; F – G: ventral valve AM F49001, internal mould and latex replica; H – I: dorsal valve AM F48995, internal mould and latex replica; J: ventral valve AM F49843, latex replica from internal mould; K – L: ventral valve AM F49011, internal mould and latex replica; M – N: dorsal valve AM F49034, internal mould and latex replica; O: ventral valve internal mould, AM F 49840; P: dorsal valve internal mould, AM F49014.**

Cocks, 1998, from the Yushan area, Jiangxi Province of South China. However, at least the former species is apparently excluded from the concept of *Ectenoglossa* outlined by Holmer and Popov (2000), which specifies only an Early Ordovician range. Popov et al. (2002) reported the presence of a weak dorsal median ridge in *E. sorbulakensis*. No such feature is mentioned as occurring in *E. minor* by Zhan and Cocks (1998) who illustrated only ventral valves.

The most distinctive feature of *Rowenaglossa* is the median septum prominently developed in the dorsal valve (though also present in a much reduced form in some ventral valves). This septum is not seen in the type species of *Ectenoglossa*, whereas it is characteristic of *Pseudolingula* and related genera, thereby supporting inclusion of *Rowenaglossa* in the Pseudolingulidae; absence of flexure lines is another similarity. The "teeth" in the ventral valve beak region, referred to by Fletcher (1964), seem to be an artifact of preservation due to a fracture in one specimen, and do not resemble the thin ridges flanking the pedicle groove seen in some specimens of *E. lesueuri*. Internal features such as the visceral field, muscle scars, and vascular markings are generally weakly impressed to absent in *Rowenaglossa*, and serve to readily distinguish it from *Pseudolingula* which displays massive thickening of the visceral area and prominent muscle scars. The dorsal valve of *R. brunnschweileri* illustrated in Fig. 7 H, I best shows details of the weakly impressed muscle field (central muscle scars) and pallial canals.

Distribution

Lower Rowena Formation, "about 8 miles (13 km) from 'Mootwingee' homestead along old coach road" according to Australian Museum register, just east of Split Rock in Mutawintji National Park, far-western NSW (Fig. 1A).

Family Zhanatellidae Koneva, 1986

***Hyperobolus* Havlíček, 1982b**

Type species: *Lingula feistmanteli* Barrande, 1879

***Hyperobolus mootwingeensis* (Fletcher, 1964)**

Fig. 8 A – P

Synonymy

1964 *Obolus Mootwingeesis* [nom. imperf. pro *mootwingeensis*] Fletcher, p. 286, pl. 31, figs 1-3, 8; pl. 32, figs 13-14.

2004 *Leptembolon*? *gnaltaensis* Fletcher, 1964; Sharp, photograph 7.

Material

Holotype AM F47427 (dorsal? valve), and paratypes AM F47422 and AM F49056, designated by Fletcher (1964), who also illustrated (but did not designate as types) AM F47428, 47439, 48963, and 48974. Of these, AM F47439 is a steinkern of the holotype specimen, and clearly therefore must be regarded as forming part of the holotype. Also mentioned, but neither illustrated nor designated as a type by Fletcher (1964), is AM F47424, which is the counterpart of paratype AM F47422. All specimens cited above are now included in the type series, and are supplemented by the following additional paratypes AM F47425, AM F48985 and AM F49056 (illustrated in Fig. 8).

Description

Shell large, distinctly triangular with straight posterolateral margins diverging at approximately 50-75 degrees from beak; maximum width attained at about four-fifths length of ventral valve and approximately three-quarters length of dorsal valve; anterolateral corners well rounded; anterior margin straight. Profile biconvex, ventral valve flattened medially, most convex in anterior quarter; dorsal valve more evenly convex. Shell moderately thick, multilayered, with concentric growth lamellae flaking anteriorly to reveal fine radial ornament and dendritic vascular markings peripherally (Fig. 8 L-N).

Details of ventral pseudointerarea uncertain, but likely to be very narrow and elongate, extending about one-third length of lateral margin of valve (poorly preserved on specimen in Fig. 8 B). Muscle field not clearly defined; there is a suggestion of scars developed medially, flanked by pair of narrower slightly longer scars in posterior quarter of valve (Fig. 8 I) but any further comment on these would be conjecture. Pallial canals also not well impressed except in posterolateral third of valve where they separate into finely dendritic canals peripherally – this is seen in several specimens e.g. Fig. 8 L-N.

Dorsal pseudointerarea entire, very short and narrow (Fig. 8 O, P). Muscle field is poorly defined, possibly with undivided umbonal scar and small subcircular posterolateral (oblique muscle?) scars (Fig. 8 O, P). Vascular markings unknown except for probable dendritic canals posterolaterally.

Dimensions

Holotype AM F47427/47439 (dorsal? valve): length 27.5 mm (slightly incomplete), width 21.6 mm. For other complete specimens, ventral valve length ranges from 16.3-32.0 mm, dorsal valve length ranges from 13.5-17.0 mm (2 specimens only); ventral valve

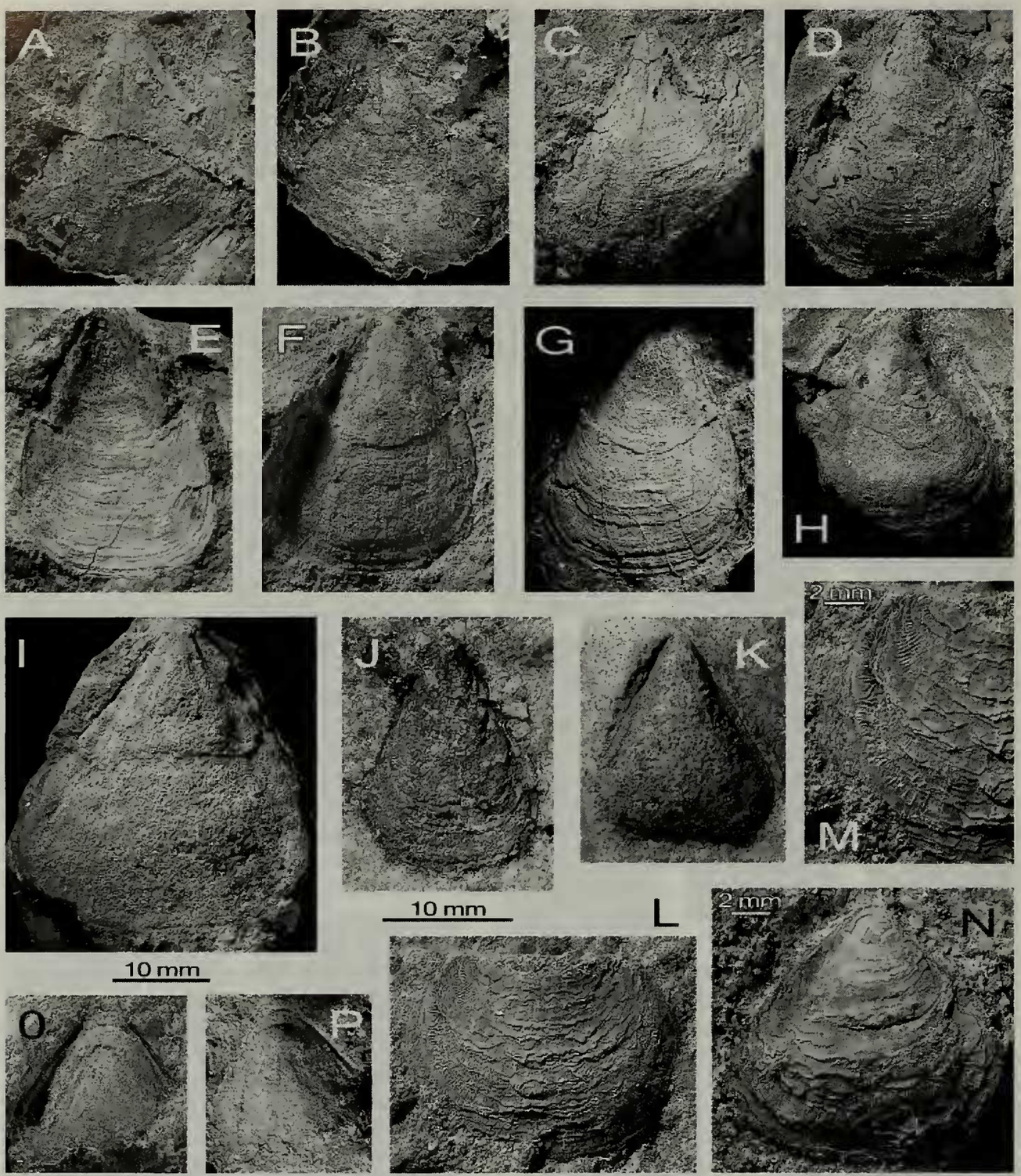

Figure 8. ***Hyperobolus mootwingeensis*** **(Fletcher, 1964), from the Koonenberry Belt, far western NSW. All specimens except K (from Bynguano Quartzite on "Bilpa" in southern Koonenberry Belt) are from the lower Rowena Formation in Mutawintji National Park. A – D: ventral valve, AM F47422 and AM F47423, (A) latex replica of partly exfoliated external mould, (B) latex replica of internal mould shown in (C), (D) counterpart external of ventral valve. E – G: dorsal? valve external mould, holotype AM F47427, and counterpart dorsal? valve internal mould AM F47439, (G) is a latex replica taken from external mould AM F47427. H: ventral valve exterior, AM F47428. I. ventral valve internal mould, AM F49056. J: ventral? valve exterior, AM F48985. K: ventral valve internal mould, MMF 15012. L – M: partial valve exterior with exfoliated shell, showing detail of shell structure and dendritic canals, AM F48963. N: dorsal valve exterior, AM F48974. O – P: fragment of posterior of dorsal valve interior, showing pseudointerarea and weakly impressed muscle scars on internal mould (O) and latex replica (P), AM F47425. Scale bar beneath I applies to specimens A – I and K; scale bar above L applies to specimens J, L and O – P; M and N have individual scale bars.**

width ranges from 14.0-29.2 mm and dorsal valve width ranges from 13.1-13.8 mm (2 specimens).

Discussion

Fletcher (1964) compared this species to *H. feistmanteli* (Barrande), at the time attributed to *Obolus* (as was originally *H. mootwingeensis*). Apart from a general agreement in characters (including presence of a marginal rim), Fletcher commented on a similarity in the appearance of marginal sinuses crossing the inner surface of the valves near the anterior-lateral margins in both species. He distinguished "*O*". *mootwingeensis* from "*O*". *feistmanteli* by the generally larger size, and more acuminate subtriangular outline, of the NSW species. Fletcher also remarked on the presence of a "posterior median sinus" which was found only in "*O*". *mootwingeensis*, referring in his description of this species to "a fine median ridge" extending from the beak in the pedicle valve. In the caption to the illustrated internal mould (Fletcher 1964, pl. 31, fig. 2) the same feature is termed a "median internal sinus". Neither is correct; the apparent fine groove is an artefact of the lighting of the specimen, and in fact represents a longitudinal fracture in the shell. Despite this slight misinterpretation, Fletcher's overall close comparison with *H. feistmanteli* (Barrande, 1879), type species of *Hyperobolus* Havlíček, 1982b remains valid, and supports the reassignment of the NSW species to that genus. Mergl (2002), who augmented the detailed description of Havlíček (1982b) with further illustrations of specimens from Bohemia, figured (Pl. 20, fig. 14) a dorsal internal mould of *H. feistmanteli* which is identical to Figure 8 M, N herein.

Of the three previously known species of *Hyperobolus*, the type *H. feistmanteli* comes from the Upper Tremadocian Třenice Formation of Bohemia. *H. fragilis* Holmer, Koneva and Popov, 1996 is known from the Middle Ordovician Zhyrykaus Formation of the Malyi Karatau Range, southern Kazakhstan, and *H. andreevae* Popov and Holmer, 1994 was described from the Akbulaksai Formation (late Early Ordovician), South Urals.

It has proven difficult to differentiate dorsal from ventral valves in *H. mootwingeensis* as both valves appear to be relatively acuminate in outline, and few internal features are known. However, even in poorly preserved material, fully grown specimens of *H. mootwingeensis* are readily distinguished in the field by their considerably larger size, much flatter profile, and more acuminate ventral valve outline compared to *Lingulobolus*? *gnaltaensis*. These criteria allow recognition of probable *H. mootwingeensis* from fragmentary remains of external moulds in the Yandaminta Quartzite, on the western flank of Mount Arrowsmith in the northwestern part of the Koonenberry Belt, at a stratigraphic level comparable with the lower Rowena Formation (J.R. Paterson, Macquarie University, pers. comm. 2006).

Distribution

Lower Rowena Formation, "about 8 miles (13 km) from 'Mootwingee' homestead along old coach road" according to Australian Museum register, just east of Split Rock in Mutawintji National Park, far-western NSW; probably also in Yandaminta Quartzite, western flank of Mount Arrowsmith (Fig. 1A). Also sporadically occurs in the Bynguano Quartzite in the southern Koonenberry Belt, 16 km south of Little Topar (MMF 15012, 15015, 21080).

Zhanatellide? indet

Fig. 4 A – C

Material

One partial ventral valve represented by internal and external moulds, MMF 44843.

Description

Valve ovoid or elliptical with slightly pointed beak, maximum width at midlength or beyond; lateral margins subparallel; anterior margin probably broadly curved (based on extrapolation from prominent growth lines which disrupt entire shell thickness); profile very low in convexity. Pseudointerarea narrow, with prominent v-shaped emarginature for pedicle emergence; a short broad ridge extends anteriorly from emarginature; small umbonal muscle scars are separated by posterior end of prominent pedicle nerve impression which splays anteriorly as two deeply incised grooves. Valve interior smooth to extremely finely pustulose medially with sporadic small pits scattered randomly.

Dimensions

Specimen length 9.1 mm, width 7.7 mm; both dimensions incomplete.

Discussion

This specimen is attributed to the Zhanatellidae on the basis of the prominent pedicle nerve impression and the v-shaped emaginature. There is insufficient material to compare with known taxa.

Distribution

Outcrop of upper Yarrimbah Formation adjacent to "Yarrimbah" and "Wilga East" property boundary, 16 km west of Parkes; late Lancefieldian (La3) to early Bendigonian (Be1).

Order Acrotretida Kuhn, 1949
Superfamily Acrotretoidea Schuchert, 1893
Family Acrotretidae Schuchert, 1893

Acrotretide gen. et sp. indet.
Fig. 9 A, B

Material

One fragmentary dorsal valve, MMMC 4190.

Description

Valve thick-shelled, robust, with external ornament of faint widely-spaced fila; larval shell relatively small; posterolateral margins converging to medial point. Pseudointerarea well developed, narrow, triangular, with straight anterior margin; median plate slightly depressed, flanked by pair of triangular propareas. Valve interior bears high, blade-like median septum supported by robust median buttress sporting prominent node on each anterolateral corner; median septum bears thickened, concave ventral edge. Muscle scars ovate, raised, relatively small but distinct.

Discussion

Although poorly preserved and lacking a corresponding ventral valve, assignation of the specimen to the Acrotretidae is supported by the presence of a well-defined pseudointerarea, a high median septum supported by a robust median buttress and thickened, raised cardinal muscle scars.

Distribution

Allochthonous limestone clast in lower Yarrimbah Formation, "Wilga East" property, 16 km west of Parkes; Early Ordovician, late Lancefieldian (La3) to early Bendigonian (Be1) age.

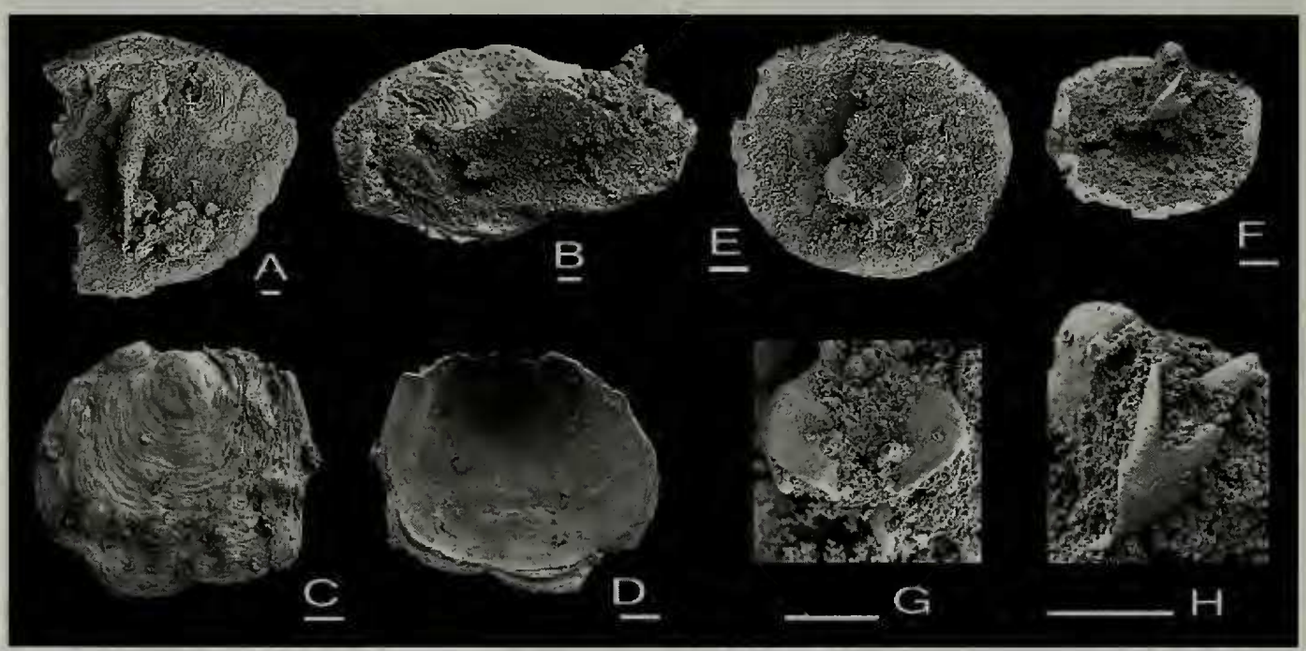

Figure 9. Acrotretide brachiopods from Early Ordovician limestones of central west NSW. A – B: Acrotretide gen. et sp. indet. from allochthonous limestone clast in lower Yarrimbah Formation, interior and oblique lateral views of dorsal valve MMMC 4190. C – D: *Otariconulus* sp. cf. *O. intermedia* (Popov and Holmer, 1994) from allochthonous limestone pod in lower Hensleigh Formation, exterior and interior views of ventral valve MMMC 4203. E – H: Ephippelasmatidae gen. et sp. nov. from allochthonous limestone pod in lower Hensleigh Formation, interior and oblique lateral views of dorsal valve MMMC 4193, and enlargements (G, H) of surmounting plate on median septum and spinose projections. Scale bar equals 100 μm.

Family Eoconulidae Rowell, 1965

***Otariconulus* Holmer and Popov, 2000**

Type species: *Otariella prisca* Popov and Holmer, 1994, by subsequent designation of Holmer and Popov (2000, p.134).

***Otariconulus* sp. cf. *O. intermedia* (Popov and Holmer, 1994)**

Fig. 9 C, D

Material

One complete dorsal valve, MMMC 4203.

Description

Valve outline subcircular, 84% as long as wide (0.57 mm long, 0.68 mm wide), moderately convex; subcircular larval shell, 81% as long as wide (0.15 mm long, 0.19 mm wide), with ornament comprising circular pits of one size; beak marginal, swollen with postlarval shell bearing rugellae superimposed on closely spaced growth lamellae; valve interior with pair of large, poorly defined cardinal muscle scars extending just short of midlength; median ridge lacking.

Discussion

This valve agrees in most respects with the description given by Popov and Holmer (1994, p. 143) of *Otariconulus intermedia* from the Lower Ordovician (Tremadoc) Satpak Formation of north-central Kazakhstan. However, in the absence of the pedicle valve, only a tentative identification is proposed.

Distribution

Allochthonous limestone in lower Hensleigh Siltstone; mid-Bendigonian age (?Be2-Be3).

Family Ephippelasmatidae Rowell, 1965

Ephippelasmatidae gen. et sp. nov.

Fig. 9 E–H

Material

One dorsal valve, MMMC 4193.

Description

Valve outline subcircular with narrow, straight posterior margin interrupted by gently protuberant beak; external ornament comprises fine, regular, closely spaced fila; valve broadly sulcate in anterior view and posteriorly with slightly inflated umbo. Pseudointerarea relatively narrow, poorly divided, propareas separated by median depression. Median septum high, arising abruptly from near midlength of valve at angle of approximately 45°, unsupported by median buttress, bearing concave surmounting platform; surmounting platform abruptly expands anteriorly to form ovate plate in plan view with deep, narrow concavity continuing medially to anterior edge of plate; lateral edges of plate folded dorsomedially beneath upper surface, appearing to continue posteriorly but diminishing in width; undersurface of plate bears single, prominent, robust, anteriorly directed spine, possibly with a second much shorter spine beneath it.

Discussion

Principal distinguishing characteristics of the single known dorsal valve include absence of a median buttress, median septum supporting ovate surmounting plate with dorsomedially folded lateral margins and a single prominent, anteriorly directed spine on its undersurface. Unfortunately, intractable matrix obscuring parts of the valve and lack of a corresponding ventral valve preclude naming of a new taxon at this time, although observable features appear to be generically distinctive and unique.

This dorsal valve is comparable with that of *Lurgiticoma* Popov (in Nazarov and Popov, 1980) in configuration of the median septum and size and shape of the pseudointerarea. In plan view the median septum of both *Lurgiticoma* and the new genus abruptly expands anteriorly and bears spines on the undersurface; however, in the latter genus the septum is not supported by a median buttress and lacks the numerous spines of *Lurgiticoma*. Although the pseudointerarea of the new genus is also similar to that of *Lurgiticoma* in being relatively long with propareas separated by a relatively large median depression, it differs in bearing a median concave indentation along the anterior margin.

Distribution

Allochthonous limestone in lower Hensleigh Siltstone; mid-Bendigonian age (?Be2-Be3).

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